Method for adjusting a transmitting power in a wireless communications network.

The invention concerns the field of wireless networks, made up of a plurality of entities intercommunicating, for example by radio channel.

More specifically, the invention relates to a method of adjusting the sending power - also called the transmitting power - of the network entities. It also relates to a wireless communication unit intended to form an entity of such a network.

The invention applies particularly to ad hoc networks, i.e. networks that do not have a pre-existing infrastructure for sending data from one entity to another.

It should be remembered that, in the field of radio waves, any signal transmitted by a sending entity to a destination entity is subject to an attenuation proportional to a power of the distance separating these entities (in practice, this power is between 2 and 6).

That is why the transmitting power of the sending entity must be sufficient for the signal effectively to reach the destination entity.

It is not, however necessary for the signal to reach the destination entity directly (this case being referred to as direct sending): it can, in practice, pass through a third party entity of the network, called an "intermediate node" or "routing node" (this case being referred to as indirect sending).

It should be noted that, in an ad hoc network, each entity can alternately serve as sending entity, destination entity or intermediate node.

In order to provide network connectivity, that is, ensure that, whatever the sending and destination entities, there is always a path enabling the message to be delivered to the receiving entity from the sending entity, it is necessary for each sending entity of the network to know the location of its adjacent entities, and vice versa.

An adjacent entity of a sending entity is any entity, for which the sending entity is near enough to receive a direct signal.

Each sending entity of the network has a corresponding sending zone, the radius of which is a function of the transmitting power of that entity.

Numerous communication protocols, with little regard for energy saving, allow for the transmitting power of any sending entity to be set in all cases to its maximum value.

While such protocols generally provide network connectivity, they do, however, involve a high energy consumption, which is detrimental to the autonomy of each entity of the network.

In the interests of energy saving, for the purpose of increasing the autonomy of the entities, it is therefore desirable to reduce the transmitting power of the network entities as much as possible while maintaining the connectivity of the network.

There are communication protocols that propose to modulate the transmitting power of a given entity according to the topology of its vicinity (see, for example, the International Patent Application published under the number WO 02/03567).

However, the protocol employed is relatively complicated and requires memories and complex

algorithms which put a strain on the costs and hamper the operation of the network.

The invention seeks in particular to resolve the abovementioned drawbacks by proposing, among other subjects, a method of adjusting the transmitting power of a sending entity in a wireless communication network enabling the energy consumption within the network to be limited simply and effectively, while ensuring the connectivity of the network.

To this end, the invention proposes, according to a first aspect, a method of adjusting the power of a sending entity in a network of wireless communicating entities, including the steps of:

- identifying the entities adjacent to the sending entity, that is, the entities of the network, separate from the sending entity, from which the sending entity (e) is able to receive the messages;

- identifying, among the adjacent entities, a minimum constellation associated with the sending entity, that is, quantitatively, the smallest set of entities adjacent to the sending entity included in a circle centered on the latter, and at least three of which form a convex polygon circumscribing the sending entity;

- identifying, among the adjacent entities not belonging to the minimum constellation, any so-called peripheral entities, whose own minimum constellation includes the sending entity;

- adjusting the transmitting power of the sending entity to a minimum value enabling the messages sent by the sending entity (e) to reach both the entities of the minimum constellation associated with the sending entity and the identified peripheral entities.

This method, applied to each entity of a wireless network, ensures its connectivity while limiting the power consumed.

In an embodiment, after having adjusted its
5   transmitting power, the sending entity sends each adjacent entity a message containing an identifier associated with said sending entity, the position of the sending entity and its minimum sending distance, that is, the radius of the smallest circle, centered on
10 the sending entity, including the minimum constellation associated with the sending entity.

The identification of the adjacent entities consists, for example, in storing in a first table, for each adjacent entity, an identifier associated with this
15 entity, the position of this entity and its minimum sending distance, that is, the radius of the smallest circle, centered on this adjacent entity, including the minimum constellation associated with this adjacent entity.

20 Preferably, each adjacent entity sends the sending entity a message containing its identifier, its position and its minimum sending distance.

Moreover, the identification of the entities belonging to the minimum constellation associated with the
25 sending entity can include the step of storing in a second table, for each adjacent entity belonging to the minimum constellation, its identifier, its position and its minimum sending distance, while the identification of the peripheral entities includes, for example, the
30 step of storing in a third table, for each of these entities, its identifier, its position and its minimum sending distance.

As for the adjustment of the transmitting power, it can include the step of selecting either the greatest of
35 the distances separating the sending entity from the

entities of the third table or, when this third table is empty, the greatest of the distances separating the sending entity from the entities of the second table, the power adjustment being made in such a way as to adapt the sending range to the selected distance.

The method described above can further include additional steps, in which, after having adjusted its transmitting power:

- the sending entity sends each of the adjacent entities a message containing its identifier, its position and its minimum sending distance,

- the tables are emptied.

According to a second aspect, the invention further proposes a wireless communication unit intended to form an entity of a network of wireless communicating entities, comprising:

- means of identifying entities adjacent to said unit, that is, the entities of the network, separate from said communication unit, from which the latter is able to receive the messages;

- means of identifying a minimum constellation associated with said communication unit, that is, quantitatively, the smallest set of entities adjacent to said communication unit included in a circle centered on the latter, and at least three of which form a convex polygon circumscribing said communication unit;

- means of identifying, among the adjacent entities not belonging to the minimum constellation, any so-called peripheral entities, whose own minimum constellation includes said unit; and

- means of adjusting the transmitting power of said communication unit to a minimum value enabling the messages sent by the communication unit to reach both the entities of the minimum constellation

associated with said communication unit and the identified peripheral entities.

Other objects and advantages of the invention will become apparent in light of the description that follows, given with reference to the appended drawings in which:

- figure 1 is a diagram representing at least partially a network comprising a relatively small number of wireless communicating entities;

- figure 2 is a diagram illustrating the topology of the network of figure 1, in which the entities are represented in node form;

- figures 3a and 3b together form a flow diagram illustrating the various steps of the method of adjusting the transmitting power of a communicating entity of the network; and

- figure 4 is a diagram representing at least partially a network comprising a large number of wireless communicating entities.

Figure 1 partially shows an interconnected wireless local area network 1. It is, for example, an *ad hoc* type radio network compliant with the IEEE 802.11b radiofrequency communication standard, also called Wi-Fi (Wireless Fidelity).

The network 1 includes a plurality of entities, of which are shown three mobile telephones 2, 3, 4, three computers 5, 6, 7 fitted with Wi-Fi modems and a microwave remote control 8.

Figure 2 illustrates the topology of the network 1, the entities 2 to 7 here being represented in the form of nodes to which are respectively assigned the letters e, B, D, A, E, F, C.

In this example, the alphabetical order according to which the nodes A to F are classified corresponds to an increasing distance from the sending node e.

Each entity 2 to 8 is fitted with a wireless communication system, the sending power (also called transmitting power) of which is adjustable.

The sending or transmission zone of the node e is defined as the portion of the space in which a receiving node is (or would be) able to receive the signals sent from the node e.

Theoretically, the transmission zone is a sphere centered on the sending entity, the radius of which varies according to the transmitting power. In reality, since the network 1 is substantially flat, the transmission zone can be likened to a disk centered on the sending entity.

Any entity of the network can directly transmit a signal to a destination entity provided that the latter is inside the sending zone of the sending entity (this is then called direct transmission).

When a destination entity is not located in the transmission zone of the sending entity, the signal can pass through a routing node or through a cascade of routing nodes, each located in the transmission zone of the preceding one, the main thing being that the signal ultimately reaches the destination entity (this is then called indirect transmission).

Figures 1 and 2 also show a number of transmission zones ZT1, ZT2, ZT3, of increasing radii which, centered on the sending telephone 2 (respectively on the sending entity e), correspond to increasing transmitting powers of its communication system.

Moreover, the telephone 2 (respectively each sending entity e) has a corresponding set of adjacent entities,

which are the entities from which the telephone is able to receive a signal.

Thus, in the example shown, the set of entities adjacent to the telephone 2 includes the telephones 3 and 4, the computers 5, 6 and 7, and the remote control 8 (respectively from a topological point of view, the set of nodes adjacent to the node e includes the nodes A to F).

The network 1 illustrated in figure 1 is proposed purely as an indication, so in the following description, the reasoning is mainly topological.

As can be seen in figure 2, the first transmission zone ZT1, with the smallest radius, contains the entities A, B and C, which together form a triangle, from which the sending entity e is excluded.

The transmission zone ZT2, of intermediate radius, contains the entities A, B, C and D, which together form a quadrilateral, from which the entity e is also excluded.

However, the transmission zone ZT3, of larger radius, contains the entities A to F which, together, form a constellation (in other words, a cloud of points) circumscribing the sending entity e, that is, a constellation within which it is possible to trace a convex polygon (at least one triangle) circumscribing the sending entity e.

Thus, in the constellation ABCDEF, the triangle AEC circumscribes the sending entity e.

Among the set of constellations ABC, ABCD, ABCDE and ABCDEF, only the constellations ABCDE and ABCDEF circumscribe the sending entity e, the constellation ABCDE being that which contains the smallest number of entities or, in other words, the constellation ABCDE being the constellation for which the circle, centered

on the sending entity, which strictly contains it, has the smallest radius (it is in this case the circle C0 of center e and radius [eE]).

By convention, such a constellation is called the minimum constellation associated with the sending entity e.

As a general rule, the minimum constellation associated with a sending entity e is defined as being, of all the constellations that are included in a circle centered on the sending entity e and which circumscribe the latter (that is, of which at least three of the entities form a convex polygon circumscribing the sending entity e), the constellation that contains the smallest number of entities.

The aim is to ensure the permanent connectivity of a network made up of a plurality of entities e_i (where i is a natural integer), so as to ensure that signals are delivered regardless of the sending entities e and receiving entities e_i. Physically, the aim is to adjust the transmitting power of a given sending entity in such a way that its sending zone encompasses at least its minimum constellation.

To this end, a connectivity criterion is defined, applicable to each entity of the network and the use of which is explained below.

This criterion is defined as follows:

Any entity e_i satisfies the connectivity criterion if the radius of its transmission zone is adjusted in such a way that this transmission zone encompasses precisely the minimum constellation associated with the entity e_i.

Below is a description of the method of controlling the transmitting power whereby, for each entity, this

adjustment can be made before this entity sends a message containing certain information listed below.

Although this method is applicable to each of the entities e_i of the network, for convenience, this

5   method is described for a given sending entity e of the network.

The first step is to identify the vicinity of the sending entity e, that is, the set of the N so-called adjacent entities e_i (i = 1 to N) from which the

10   sending entity e is able to capture messages.

To this end, the following are entered in a first table L, for each entity e_i (i = 1 to N):

- its identifier e_i,

- the position pos_i of the entity e_i, characterized,

15   for example, by the two-dimensional Cartesian coordinates (x_i, y_i) of the entity e_i in a predetermined flat frame of reference relative to which are positioned all the entities of the network, and

20   - the minimum sending distance of the entity e_i, that is, the distance separating the entity e_i from the most distant of the entities belonging to its associated minimum constellation.

This data, sent by each entity e_i and received by the

25   sending entity e, is stored in the latter. For example, the table L is stored in a memory that is provided in the sending entity e.

This data concerning the vicinity of the sending entity e is entered in the table L in ascending order of index

30   number i according to the distance separating the sending entity e from the entities e_i. In other words, the index number i = 1 is assigned to the entity nearest to the sending entity e, and i = N to the entity furthest away. This classification can be

performed by means of a simple comparator, since it is possible to deduce the distance separating the sending entity e from each of the adjacent entities e_i from their respective coordinates.

5   In practice, if the entities are identified by their Cartesian coordinates (the coordinates of the sending entity being denoted x, y and the coordinates of the adjacent entities x_i, y_i, i = 1 to N), the distance d_i separating the sending entity from the adjacent entity
10   e_i is given by the following standard formula:

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2}$$

Thus, the table L takes the form of a matrix with four columns and N rows:

$$L = \begin{bmatrix} e_1 & x_1 & y_1 & p_1 \\ e_2 & x_2 & y_2 & p_2 \\ \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots \\ e_N & x_N & y_N & p_N \end{bmatrix}$$

15   The next step is to identify, from the adjacent entities e_i, the entities belonging to the minimum constellation associated with the sending entity e.

To this end, a second table K is formed (with four columns and an as yet undefined number of rows) from
20   the first table L, as follows.

The first step is to assign the value 1 to the index number i.

The data relating to e_1 is transferred to the table K, that is, it is entered in the table K and deleted from
25   the table L.

This operation is repeated with, on each repeat, the index number i being incremented by one unit, as long as the entities of the thus formed table K do not allow

compliance with the connectivity criterion for the sending entity e.

On each iteration, a check is carried out to see whether the connectivity criterion is satisfied. When the connectivity criterion is satisfied, incrementing is stopped.

The table K then contains the P entities e_i (i = 1 to P, where P $\leq$ N) that form the minimum constellation associated with the sending entity e.

The table K is used to calculate the minimum sending distance, denoted p, of the sending entity e. This minimum sending distance p is equal to the distance separating the entity e from the most distant entity of the minimum constellation, that is, in the table K, the furthest away from the sending entity e. Given the classification already carried out, this is the entity e_p located on the last row of the table K.

If it has not been stored previously, the distance d_p between the sending entity e and the entity e_p furthest away from the sending entity e in the minimum constellation is then recalculated.

As an example, in the case of the network illustrated in figure 2, if the entity e is taken as the sending entity, its minimum sending distance is the distance separating the entity e from the entity E.

It should be noted that if P = N, then the table L is empty, and the table K is equal to the original table L.

Physically, this means that the minimum constellation of the sending entity e includes all of its vicinity, that is, all of the adjacent entities e_i, for i = 1 to N.

In this case, the next step is to adjust the transmitting power of the entity e such that the radius R of its transmission zone ZT is (theoretically) equal to its minimum sending distance p. In practice, the transmitting power is adjusted to the minimum value which yet allows a message sent by the sending entity to reach all the entities of the minimum constellation associated with the sending entity.

The next step, for the entity e, consists in sending a message containing its own data, in other words, its identifier e, its position (x, y) and its minimum sending distance p.

This data is received by the entities e_i included in the transmission zone ZT, in this case, by the entities e_i forming the minimum constellation of the sending entity e.

If P < N, then the table L has not been fully emptied on forming the table K, and contains the data e_i, x_i, y_i and p_i concerning the N-P entities remaining after forming the table K, these entities being both adjacent to the sending entity e and located outside its minimum constellation.

Among these entities, it is desirable to identify those whose minimum constellation contains the sending entity e, if any such exist.

It is, in practice, desirable for the data, that is, the identifier e, position (x, y), minimum sending distance p, of the sending entity e to reach each of these peripheral entities, since, as we have just seen, this data is essential in calculating the minimum sending distance associated with each of these peripheral entities.

Thus, the next step is to assign the index number i the value P+1.

If it has not been stored previously, the distance d_i between the sending entity e and each entity e_i remaining in the table L (that is, each entity located outside the minimum constellation) is recalculated.

5 Then, this distance d_i is compared with the minimum sending distance p_i of the corresponding entity e_i. In other words, a check is carried out to see whether the sending entity e is contained in the minimum constellation associated with that entity e_i.

10 If $d_i > p_i$, then the sending entity e is located outside the minimum constellation associated with the entity e_i. It is therefore necessary only for the data concerning the sending entity e to reach the entity e_i.

As long as i is less than N, the index number i is 15 therefore incremented by one unit and this operation is repeated for the next entity.

If, however, $d_i \leq p_i$, then the sending entity is effectively contained in the minimum constellation associated with the entity e_i. It is therefore 20 essential to ensure that the signal sent by the sending entity e reaches (directly) the entity e_i.

The data concerning the entity e_i, in other words the identifier e_i, its position x_i, y_i and its minimum sending distance p_i, is therefore entered in a third 25 table J, which, like the table K, is a matrix with four columns and an as yet undefined number of rows.

As long as i is strictly less than N, the index number i is incremented by one unit and the operations that have just been described are repeated for the 30 subsequent entities.

These operations are stopped when i = N, that is, when all the distances separating the sending entity e from the entities e_i (i = P+1 to N) have been calculated and

compared with the minimum sending distances p_i associated with the entities e_i.

Two assumptions then emerge, depending on whether the third table J is empty or whether it contains at least 5 one entity.

If the third table J is empty, then there is no peripheral entity. In other words, in the vicinity of the sending entity e, outside of its associated minimum constellation, there is no entity whose own minimum 10 constellation contains the sending entity e.

In this case, the next step consists in adjusting the transmitting power of the entity e such that the radius R of its transmission zone ZT is (theoretically) equal to the minimum sending distance p. In practice, the 15 transmitting power is adjusted to the minimum value that enables a message sent by the sending entity e to reach all the entities of the minimum constellation associated with the sending entity.

The next step consists, for the entity e, in sending 20 its data, in other words its identifier e, its position x, y and its minimum sending distance p.

This data is received by the entities e_i included in the transmission zone ZT, in this case the entities e_i forming the minimum constellation of the sending entity 25 e.

If the third table J is not empty, then the subsequent steps consist in identifying, from the peripheral entities e_i, listed in the third table J, the entity e_j furthest away from the sending entity e.

30 Given the classification already carried out, it is the entity e_j located on the last row of the third table J, then in (re)calculating the distance d_j separating the sending entity e from this most distant entity e_j, if

this distance d_j has not been stored before or when forming the first table L.

The next step is to adjust the transmitting power of the entity e so that the radius R of its transmission zone ZT is (theoretically) equal to the distance d_j.

In practice, the transmitting power is adjusted to the minimum value that enables a message sent by the sending entity e to reach all the peripheral entities identified for the sending entity e.

The next step then consists, for the entity e, in sending its data, that is, its identifier e, its position x, y and its minimum sending distance p.

This data is received by the entities e_i included in the transmission zone ZT, including the peripheral entities e_i which, outside the minimum constellation, need the data concerning the sending entity e to perform their own calculation of their minimum sending distance p_i, which is calculated according to the procedure described above, the method that has just been described being, in effect, applicable, as we have already indicated, to each entity e_i of the network.

Once the sending entity e has sent its data, the tables that are not empty are emptied pending the subsequent repetition of the method.

Naturally, the interval between repeats of the method can be adjusted for each entity, in particular according to its own mobility, or more generally for all of the network.

Physically, in a geographically limited area network with a large number of mobile entities (for example, mobile telephones) relative to the total number of entities, the interval for the mobile entities can be set to a few seconds.

However, in a geographically wide area network with only a small number of mobile entities, this interval can reach several tens of seconds, even exceed a minute.

5   The method that has just been described, which is applied simultaneously and in parallel to this method to all the entities of the network is used to ensure the connectivity of the latter, because the transmitting power of each sending entity is adjusted
10 so as to encompass at least the minimum constellation associated with that entity (which means that there is an assurance that the nearest entities surrounding the sending entity will be able to receive, and, where necessary, relay, the signal from the sending entity),
15 and, when they exist, the peripheral entities for which the signal from the sending entity is necessary for the method to operate.

It may be that a sending entity e is located, at least temporarily, at the edge of the network, that is, that
20 no minimum constellation can, topologically, be associated with it.

In this case, in order to ensure the operation of the network, the transmitting power of this entity e is set to its maximum before sending its data, the minimum
25 sending distance p being adjusted to be equal to the radius of the corresponding transmission zone.

Naturally, any wireless communication unit (such as a mobile telephone or a computer) intended to implement the method that has just been described will be
30 provided with means designed for this purpose, specifically for implementing each step of the method.

Physically, these means can take the form of a computer program loaded in a processor installed in this unit.

Two exemplary applications of the method just described
35 to one and the same network are given below,

illustrated in figure 4, comprising 20 entities referenced A to T and positioned in an orthogonal, flat frame of reference XY.

Example 1

5　In this example, the entity A is chosen as the sending entity, and it is assumed that it is on the point of transmitting its data.

As can be seen in figure 4, the entity A has a corresponding vicinity V_A which includes the entities

10　B, C, D, E, F, G, H, O, P, T.

Below is a list, for each entity A, B, C, D, E, F, G, H, O, P, T, in the form of a set of three values (expressed, for example, in meters), of its coordinates in the XY frame of reference (the first two values),

15　and its minimum sending distance (the third value):

A (47, 58, 18)
B (64, 65, 18)
C (43, 70, 22)
D (37, 60, 22)
20　E (41, 45, 15)
F (64, 44, 20)
G (72, 59, 28)
H (59, 84, 22)
O (37, 85, 14)
25　P (22, 45, 19)
T (40, 31, 20)

The sending entity A receives the data from the entities B, C, D, E, F, G, H, O, P, T in its vicinity V_A.

30　The first step is to assign each of the entities D, C, E, B, F, H, O, P, T, G (arranged in order of their distance from the sending entity A) the index numbers 1 to 10.

Then, the table L is constructed from the data received from the vicinity of the entity A. The result from the values given above is that the table L is created as follows:

$$L = \begin{bmatrix} e_1 & 37 & 60 & 22 \\ e_2 & 43 & 70 & 22 \\ e_3 & 41 & 45 & 15 \\ e_4 & 64 & 65 & 18 \\ e_5 & 64 & 44 & 20 \\ e_6 & 59 & 84 & 22 \\ e_7 & 37 & 85 & 14 \\ e_8 & 22 & 45 & 19 \\ e_9 & 40 & 31 & 20 \\ e_{10} & 72 & 59 & 27 \end{bmatrix}$$

5

From the table L, the table K is constructed in order to determine the minimum sending distance p of the entity A.

Successive iterations show (as appears geometrically in figure 4) that the minimum constellation of the entity A is made up of the entities e_1, e_2, e_3 and e_4, that is, the entities B, C, D, E.

10

The table K is therefore created as follows:

$$K = \begin{bmatrix} e_1 & 37 & 60 & 22 \\ e_2 & 43 & 70 & 22 \\ e_3 & 41 & 45 & 15 \\ e_4 & 64 & 65 & 18 \end{bmatrix}$$

whereas the table L is created as follows:

15

$$L = \begin{bmatrix} e_5 & 64 & 44 & 20 \\ e_6 & 59 & 84 & 22 \\ e_7 & 37 & 85 & 14 \\ e_8 & 22 & 45 & 19 \\ e_9 & 40 & 31 & 20 \\ e_{10} & 72 & 59 & 27 \end{bmatrix}$$

It is deduced from the table K that the entity furthest from the sending entity A is the entity e_4 (B), the distance d_4 separating the entities A and B being equal to 18 m.

5 The result is that the minimum sending distance p of the entity A, equal to d_4, is 18 m.

Any peripheral entities are then identified.

Successive calculations provide the distances separating the entity A from the entities e_5 (F) to e_{10} 10 (T), these distances being systematically compared to the values p_5 to p_{10} of the minimum sending distances of the corresponding entities. The values d_5 to d_{10} are as follows:

$$d_5 = 22 \text{ m}$$
15
$$d_6 = 28 \text{ m}$$
$$d_7 = 28 \text{ m}$$
$$d_8 = 29 \text{ m}$$
$$d_9 = 29 \text{ m}$$
$$d_{10} = 30 \text{ m}$$

20 Now, it emerges from table L that the values of the minimum sending distances p_5 to p_{10} are as follows:

$$p_5 = 20 \text{ m}$$
$$p_6 = 22 \text{ m}$$
$$p_7 = 24 \text{ m}$$
25
$$p_8 = 19 \text{ m}$$
$$p_9 = 20 \text{ m}$$
$$p_{10} = 27 \text{ m}$$

Thus, whatever the value of i (i = 5 to 10), d_i is strictly greater than p_i, which means that none of the 30 minimum constellations of the entities e_5 (F) to e_{10} (G) contains the sending entity A. No table J is therefore constructed.

Also, the next step consists in adjusting the transmitting power of the entity A so that the radius of its transmission zone ZT_A is equal to its minimum sending distance, that is, the distance d_4, separating
5   the entities A and B.

The next step consists, for the entity A, in sending its data, that is, its identifier A, its position (identified by the Cartesian values 47 and 58), and its minimum sending distance, the value of which is equal
10 to 18.

This data is received by the entities included in the transmission zone of the entity A, in other words the entities B, C, D and E.

Example 2

15 In this example, the entity F is chosen as the sending entity, and it is assumed that it is on the point of transmitting its data.

As can be seen in figure 4, the entity F has a corresponding vicinity V_F which includes the entities
20 A, B, C, D, E, G, L, M, N, T.

Below is a list, for each entity A, B, C, D, E, F, G, L, M, N, T, in the form of a set of three values (expressed, for example, in meters), of its coordinates in the XY frame of reference (the first two values),
25 and its minimum sending distance (the third value):

A (47, 58, 18)
B (64, 65, 18)
C (43, 70, 22)
D (37, 60, 22)
30 E (41, 45, 15)
F (64, 44, 20)
G (72, 59, 28)
L (59, 22, 33)
M (89, 40, 38)

N (77, 76, 22)
T (40, 31, 20)

The sending entity F receives the data from the entities A, B, C, D, E, G, L, M, N, T, located in its vicinity V_F.

The first step is to assign each of the entities G, L, B, A, E, M, T, D, C, N (arranged in order of their distance from the sending entity F) the index numbers 1 to 10.

Then, the table L is constructed from the data received from the vicinity of the entity F. The result from the values given above is that the table L is created as follows:

$$L = \begin{bmatrix} e_1 & 72 & 59 & 28 \\ e_2 & 59 & 22 & 33 \\ e_3 & 64 & 65 & 18 \\ e_4 & 47 & 58 & 18 \\ e_5 & 41 & 45 & 15 \\ e_6 & 89 & 40 & 38 \\ e_7 & 40 & 31 & 20 \\ e_8 & 37 & 60 & 22 \\ e_9 & 43 & 70 & 22 \\ e_{10} & 77 & 76 & 22 \end{bmatrix}$$

From the table L, the table K is constructed, in order to determine the minimum sending distance p of the entity F.

Successive iterations show (as appears geometrically in figure 4) that the minimum constellation associated with the entity A is made up of the entities e_1, e_2 and e_3, that is, G, L and B (figure 4).

The table K is created as follows, the index numbers being reassigned to the entities B, G and L from 1:

$$K = \begin{bmatrix} e_1 & 72 & 59 & 28 \\ e_2 & 29 & 22 & 33 \\ e_3 & 64 & 65 & 18 \end{bmatrix}$$

whereas the table L is created as follows:

$$L = \begin{bmatrix} e_4 & 47 & 58 & 18 \\ e_5 & 41 & 45 & 15 \\ e_6 & 89 & 40 & 38 \\ e_7 & 40 & 31 & 20 \\ e_8 & 37 & 60 & 22 \\ e_9 & 43 & 70 & 22 \\ e_{10} & 77 & 76 & 22 \end{bmatrix}$$

The result from the table K is that the entity furthest
5   from the sending entity F is the entity e_3 (B), the
distance d_3 separating the entities F and B being equal
to 20 m.

It is deduced from this that the minimum sending
distance p of the entity F, equal to d_3, is 20 m.

10   Any peripheral entities are then identified.

Successive calculations provide the distances
separating the entity F from the entities, identified
in the table L above, e_4 (A) to e_{10} (N), these distances
being systematically compared to the values p_4 to p_{10} of
15   the minimum sending distances of the corresponding
entities. The values d_1 to d_7 are as follows:

$$d_4 = 22 \text{ m}$$
$$d_5 = 23 \text{ m}$$
$$d_6 = 25 \text{ m}$$
20   $$d_7 = 23 \text{ m}$$
$$d_8 = 31 \text{ m}$$
$$d_9 = 33 \text{ m}$$
$$d_{10} = 34 \text{ m}$$

25   It emerges from the table L that the values of the
minimum sending distances p_1 to p_7 are as follows:

$$p_4 = 18 \ m$$
$$p_5 = 15 \ m$$
$$p_6 = 38 \ m$$
$$p_7 = 20 \ m$$
$$p_8 = 22 \ m$$
$$p_9 = 22 \ m$$
$$p_{10} = 22 \ m$$

As can be seen, d_6 is less than p_6, which means that the sending entity F is contained in the minimum constellation of the entity e_6 (M).

Consequently, the entity e_5 is entered in the matrix J associated with the entity F.

Since this property is not satisfied for any other entity entered in the matrix L, the matrix J contains only the data associated with the entity M.

Consequently, the transmitting power of the entity F is set so that the radius R of its transmission zone ZT_F is equal to the distance d_6, or 25 m.

The next step consists, for the entity F, in sending its data, in other words its identifier F, its position (the values 64 and 44) and its minimum sending distance, equal to 20.

This data is received by the entities included in the transmission zone ZT_F of the entity F, in other words the entities A, B, E, G, L and M.